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An integer linear program to schedule an Army installation's maneuver training

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THESIS

AN INTEGER LINEAR PROGRAM TO SCHEDULE AN ARMY INSTALLATION'S MANEUVER TRAINING

by

Fatih Kasimoglu

June 2004

Thesis Advisor:	Robert F. Dell
Second Reader:	David H. Olwell

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This thesis develops an integer linear program called MSAMT (Model to Schedule Army Maneuver Training) to schedule an Army installation's maneuver training. We demonstrate MSAMT using a data set containing 261 platoon-level, 67 company-level and 18 battalion-level units, and 7 major training areas located at Fort Hood, Texas. Using a typical near-term planning horizon from 6 to 8 weeks, MSAMT schedules daily training for a randomly selected set of the stationed units and training requirements. For a 6-week time period and almost 65% (63 platoons 16 companies and 5 battalions) of the units there are 151 platoon-level, 51 company-level and 11 battalion-level required tasks of which MSAMT can schedule 93%. When the subset of units is increased to 80% (75 platoons, 20 companies, 6 battalions), there are 187 platoon-level, 62 company-level and 11 battalion-level tasks of which MSAMT can schedule only 85%. Maintaining the 80% unit level but having an 8 week-period increases required training achieved to 94%. Such results can help determine the ability of an Army installation to satisfy training requirements of its stationed units as well as identify a shortage or excess in available training land. It can show the training impact of changing the quantity of units at an installation and thereby aid in base realignment and closure decisions.

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AN INTEGER LINEAR PROGRAM TO SCHEDULE AN ARMY INSTALLATION'S MANEUVER TRAINING

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EXECUTIVE SUMMARY

This thesis develops an integer linear program called MSAMT (Model to Schedule Army Maneuver Training) to schedule Army maneuver training of the units located at an Army base. As a result of the schedule obtained, it also provides a measure of the ability of a base to support the maneuver training of its units.

A sample MSAMT implementation uses a data set of the units located at Fort Hood, Texas and the training areas at this base. The area and time requirement for each unit to perform its task is from Training Circular 25-1. The time period covered is 6 to 8 weeks, called a near-term training plan in Army Field Manual 7-1. For a 6-week training period, 63 platoons, 16 companies and 5 battalions (65% of the units) are randomly chosen for the training set. MSAMT assigns a random initial training level of the units resulting in 151 platoon-level, 51 company-level and 11 battalion-level tasks. MSAMT schedules all required battalion and company tasks but is only able to schedule 75% of the platoon tasks. Using a weighted sum of these platoon, company and battalion percentages we aggregate these into a single base ability value of 93%. All training areas are extensively used.

Next some observations are made about the impact of additional units in the training set as well as additional time and area available. When the subset of units is increased to 80% (75 platoons, 20 companies, 6 battalions), there are 187 platoon-level, 62 company-level and 11 battalion-level tasks of which MSAMT can schedule only 85%. Maintaining the 80% unit level but having an 8 week-period increases required training achieved to 94%. Maintaining an 80% unit level for a 6-week time period but adding 50 km^2 more land obtains a value of 90%.

MSAMT can be used as a tool to schedule the maneuver training of an Army base and to evaluate the ability of an Army base to support the maneuver training. It can determine the amount of excess or shortage in training land at an Army installation. It can show the training impact of changing the quantity of units at an installation and thereby aid in base realignment and closure decisions.

I. INTRODUCTION

The U.S. Army's mission is to fight and win the nation's wars and achieve the directed national objectives. The training of soldiers, leaders, and units is a crucial element to being prepared for this mission. Individual and collective training should provide the opportunity to practice battle-focused mission essential tasks in a realistic environment [Department of the Army, Training Circular 25-1, 2001, p. 1.1]. This training requires substantial effort both in planning and execution. Are units given a training schedule that meets their requirements? Can a given installation support the maneuver training requirements of its stationed units? To help answer these questions, this thesis develops an integer linear program called MSAMT (Model to Schedule Army Maneuver Training) to schedule Army maneuver training of units located at an Army installation.

One of the U.S. Army's training principles is that training conditions should be as realistic as possible. The type of training that is tough, realistic, and challenging both intellectually and physically excites and motivates soldiers and leaders, as well as preparing them for what they may encounter. Realistic training builds competence and self-confidence. [Department of the Army, Field Manual 7-0, 2002, p. 2.6]

Once individuals and units have trained to a required level of proficiency, leaders should plan collective training to obtain and maintain training proficiency. This can only be achieved by training the essential tasks at a certain frequency [General Accounting Office (GAO), 1991]. This frequency is specified by task in TC 25-1. Having a sufficient training area is crucial in order to create the realistic environment for training and provide units with the opportunity to repeat critical tasks.

Training land is also of great concern when deciding to realign or close a base.

> Since 1988, the Department of Defense (DOD) has undergone four rounds of base realignments and closures and has reportedly reduced its base infrastructure by about 20 percent, saving billions of dollars in the process. DOD reported that, as of December 2002, it had disposed of about 272,000 acres (53 percent) of an approximately 511,000 acres that it had identified during the previous base closure rounds as unneeded and being made to available to others for reuse. [GAO 2003]

When deciding to close an Army installation, an important criterion is its ability to provide its units with necessary training land. It is an installation commander's responsibility to analyze whether or not the available training land is able to meet the requirements. [Department of the Army, Army Regulation 210-21, 1997, p. 3]

A. ARMY TRAINING

The planning and execution of Army training is the subject of many Army manuals, training circulars and Army training programs. Having an efficient, battle-focused, realistic training program is one of the greatest concerns of a commander. In fact, it is the only way to prepare units for battle. The methods the Army uses to train should be consistent with the guidelines stipulated in its related documents.

1. Army Training Documents

This section reviews several documents used by the Army in its training plans and execution. These documents form a basis for schedules in this thesis. FM 7-0, Training the Force; FM 7-1, Battle Focused Training and TC 25-1, Training Land are division or higher-level training documents. ARTEP 71-2-MTP, Mission Training Plan for the Tank and Mechanized Battalion Task Force only relates to training at the battalion level and below, which is the main concern of this thesis.

a. FM 7-0, Training the Force

FM 7-0 is the Army's main doctrine for units at all levels. It contains fundamentals for all individuals, leaders and units. It provides the necessary guidelines on the planning, execution, and assessment of Army training and leadership development. It answers the question: "How should the Army train?" [Department of the Army, Field Manual 7-0, 2002, p. iv]

Some of the related topics covered in this manual are the manner in which the Army trains, the principles of training, the Army training management cycle, the mission essential task list development, the training plans (long-term, short-range, near-term), and the execution of training. [Department of the Army, Field Manual 7-0, 2002, p. iv]

b. FM 7-1, Battle Focused Training

FM 7-1 is a doctrinal basis for Army training. It explains how Army training should be planned, prepared, executed and assessed. It is a guide that helps commanders at all levels to conduct Army training in the appropriate manner. [Department of the Army, Field Manual 7-1, 2003, pp. xii and 1.1]

FM 7-1 is a common training language for the Army that clarifies leaders' training responsibilities and describes the manner in which Army training should be executed [Department of the Army, Field Manual 7-1, 2003, pp. xii and 1.1]. Among many other training related topics, it describes in detail the planning and execution of Army training.

c. ARTEP 71-2-MTP, Mission Training Plan for the Tank and Mechanized Battalion Task Force

ARTEP 71-2-MTP is a mission-oriented training program that focuses on training at the tank and mechanized battalion level. It is a tactical training and evaluation program for the battalion task force, but it also provides some guidelines about how the training should be conducted at the battalion level. Among many other topics, it discusses the mission essential tasks for the battalion task force. [Department of the Army, Army Training and Evaluation Program 71-2, 2001, p. 1.2]

Some of the related topics covered in this document are unit training, training plans, training exercises, training and evaluation outlines.

d. TC 25-1, Training Land

MSAMT obtains most of its parameters such as the area and day requirements for each unit by mission from TC 25-1. TC 25-1 also describes the derivations of these numbers. It provides some definitions about training areas such as heavy maneuver training areas, light maneuver training areas, contiguous training areas, non-contiguous areas and so forth. However, it mainly discusses the training area requirements for the units at the division level and below that include the required frequency for the mission in order to maintain the necessary level of performance in a task and the required number of training days per iteration for each task. [Department of the Army, Training Circular 25-1, 2001, p. A.2]

2. How the Army Trains

Some Army institutions such as schools, Army training centers, and NCO academies train soldiers and leaders in order to prepare them to assume their responsibilities in their to be assigned units. Having learned the doctrine, techniques, tactics and procedures, leaders and soldiers participate in their respective units. The focus of the units trained is on the specified mission essential tasks to reach their standards. Thus, units, leaders and soldiers first train as an organic unit but then they become an integrated part of a system. [Department of the Army, Field Manual 7-0, 2002, p. 1.4]

Some of the important documents on Army training were previously mentioned. The guidelines in these documents are decisive when planning Army training.

a. Principles of Army Training

Field manual 7-0 discusses 10 principles of training that should be followed by leaders and commanders at all echelons. As commanders train their units, they need to prioritize in accordance with these principles. [Department of the Army, Field Manual 7-0, 2002, p. 2.1]

"Train for combat proficiency" is one such principle. It is crucial to offer the units a realistic training environment to obtain a good level of combat proficiency. To provide the units with realistic conditions, it is absolutely necessary to provide them the required amount of training land needed to perform their mission essential tasks.

b. Resources of Army Training

Many resources are used to provide Army units with the necessary conditions needed to perform their training. During the planning phase of the training, all these constrained resources should be considered and an appropriate course of action developed in case of a shortage of some of these resources. The deletion of the low-priority training requirements is one method used to handle a shortage of training resources while another is to request additional resources from the higher command. [Department of the Army, Field Manual 7-0, 2002, p. 4.17]

One of the important Army training resources mentioned in FM 7-0 is the available training land; the model developed in this thesis can help ascertain this availability.

3. Scheduling an Installation's Maneuver Training

Army training has three categories of plans: long-range, short-range and near-term. Commanders at all levels are responsible for giving guidance, assessment of training and publishing training plans. Efficiency and mission-oriented planning is the key in order to obtain the intended output from training. [Department of the Army, Field Manual 7-1, 2003, pp. 4.3-4.46]

Long-range plans cover a time period up to 10 years at a major Army command level and 1 year at the active component company level. They contain proposed command training guidance and major training events. They are published early enough to provide the subordinate units the time necessary to prepare their own training plans. Short-range training plans describe the guidance in the long-range plans in more detail and extend three to six months for active component units. As with long-range plans, short-range plans should also provide the subordinate units the lead-time necessary to prepare their own short-term plans. Giving more specific guidance on training, near-term plans extend six to eight weeks for active component units. They focus on the execution of the short-term plans, and then create feasible training schedules. [Department of the Army, Field Manual 7-1, 2003, pp. 4.52-4.72]

Near-term plans produce very detailed training schedules so that the subordinate units can execute their training tasks without questions. Among many other specifications and details a good training schedule should contain: the area where training will be executed, the time training starts, and the time training ends. [Department of the Army, Field Manual 7-1, 2003, pp. 4.52-4.78]

Of course, the time and area allocated for each training task should meet the requirements specified in TC 25-1. Table 1 presents a sample training schedule possessing the aforementioned specifications at the battalion level.

Unit Type	Battalion	Company	Platoon	Task	Area	Day-1	Day-2	Day-3	Day-4	Day-5
Combat	BN-1	CO-1	PLT-1	Task-1	Area-1	X		X		
					Area-2					
				Task-2	Area-1					
					Area-2					X
			PLT-2	Task-1	Area-1					
					Area-2	X		X		
				Task-2	Area-1					X
					Area-2					
		CO-2	PLT-1	Task-1	Area-1	X		X		
					Area-2					
				Task-2	Area-1					
					Area-2					X
			PLT-2	Task-1	Area-1					
					Area-2	X		X		
				Task-2	Area-1					
					Area-2					X
	BN-2	CO-1	PLT-1	Task-1	Area-1					
					Area-2	X		X		
				Task-2	Area-1					
					Area-2					X
			PLT-2	Task-1	Area-1	X		X		
					Area-2					
				Task-2	Area-1					
					Area-2					X
		CO-2	PLT-1	Task-1	Area-1	X			X	
					Area-2					
				Task-2	Area-1					
					Area-2					
			PLT-2	Task-1	Area-1					
					Area-2	X			X	
				Task-2	Area-1					
					Area-2					

Table 1. Sample Training Schedule at the Battalion Level. Cross Marks Indicate the Start of Each Task.

B. OVERVIEW OF THIS THESIS

The focus of this thesis is to schedule the maneuver training of units at the battalion level and below located at an installation. The resulting schedule also makes it possible to evaluate the military value of an installation with respect to its ability to support maneuver training.

As mentioned previously, the near-term plan of a unit results in a very detailed schedule. The bulk part of this schedule, however, is who will train, where and for how much time. TC 25-1 lists all the unit levels, their respective mission essential tasks, the number of days each task requires and the iteration required in a year for each task. Using the day and area requirements specified for each task at each unit level in TC 25-1, MSAMT develops a schedule.

The military value of an installation has many aspects including its ability to support maneuver training. Through the training schedules obtained, MSAMT makes it possible to assess the military value of an installation with respect to its ability to support maneuver training.

Chapter II provides introductory information about some previously developed training land models. Chapter III presents a MSAMT formulation. Chapter IV discusses results from a sample study. Chapter V offers conclusions.

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II. RELATED MODELS

Land is not only one of the most important resources of Army training, but is a valuable asset from many other perspectives as well. The increase in population, the rapid expansion of urbanization, and environmental concerns are some of the reasons to contemplate better utilization of the available land resources. Gillman [1993] discusses a linear program to evaluate an Army base's ability to support maneuver training. He mentions three other models that the Army still uses: ATLAM (Army Training Land Assessment Model), RFMSS (Range Facility Management Support System), and ITAM (Integrated Training Area Management). This thesis provides some introductory information about the model found in Gillman [1993] as well as the related models he mentions.

A. A LINEAR PROGRAM BY GILLMAN

Gillman [1993] develops a linear program to find an installation's ability to support maneuver training. His main input is the day and area requirements specified in TC 25-1 for each task. The linear program seeks a solution that satisfies required training by matching the required amount of land necessary in order to perform their mission essential tasks specified in TC 25-1 in a certain training period.

The linear program described by Gillman [1993] does not schedule training tasks but rather evaluates whether sufficient land and days exists to accommodate given tasks. Because he uses a linear program, a given training exercise can be unrealistically scheduled over different areas. He does not provide a specific schedule of a training exercise to training areas on given days. He does however provide an optimistic evaluation of what training can be accomplished for a given year.

B. ATLAM

Applying an acre-day approach, ATLAM determines the total amount of land needed for a specific task at a designated level. If, for example, there are 20 companies located at an installation, and if they are to perform a "movement to contact" task, ATLAM indicates the amount of land needed for all these companies to complete their given task. [Department of the Army, Training Circular 25-1, 2001, pp .3.2-3.3]

However, cases exist in which a platoon can train at the same time as unaffiliated companies. Additionally companies in the same battalion may have different training tasks depending on their unit types (combat, combat support or combat service support).

ATLAM also does not consider the land type. A mechanized or an armor unit cannot operate in a very heavily wooded area whereas a combat service unit such as a medical platoon prefers that type of area. [Gillman, 1993]

C. ITAM

ITAM is mainly concerned about the environmental impact of training on land. A summary of the goals that ITAM tries to achieve is:

> Land restoration and revegetation, decision support for land use and planning, range and training area enhancements, pollution prevention (air, water, noise, solid waste), soil conservation and erosion control, wildlife conservation, archaeological site protection and preservation. [Charis, 2004]

The types of questions answered in this thesis, for example, what is the ability of an installation to support maneuver training, or what is an optimal scheduling with respect to the available maneuver areas, are not addressed in ITAM.

D. RFMSS

RFMSS, a software program, helps track the availability of the training land. Through an automated range and training area management system, it centralizes the scheduling of training assets. It enables Army units to request ranges and training areas through local area network connections [Department of the Army, Training Circular 25-1, 2001, p. 2.5]. However, it is not designed to question the overall ability of an installation to support maneuver training. Whether or not the amount of land given to a unit for a specific task is sufficient, is not a concern of RFMSS.

E. MSAMT COMPARED TO PREVIOUS MODELS

MSAMT combines the two problems of scheduling the maneuver training of units located at a base and evaluating the ability of the base to support maneuver training, which are not handled together in any of the aforementioned models. MSAMT schedules maneuver training and ascertains the extent to which the requirements specified in TC 25-1 are met.

III. A MODEL TO SCHEDULE ARMY MANEUVER TRAINING (MSAMT)

A. MSAMT

As in Gillman [1993], this thesis uses the term "major training areas" as the groups of training areas that are contiguous and their categorizations as "Go", "Slow Go", and "No Go". "Go" refers to the area that is unrestricted for use by any type of unit. "Slow Go" refers to the area that is partially restricted for use by tracked and wheeled units. "No Go" refers to the area that is restricted for use by tracked and wheeled units. A task can only be scheduled on one of these major training areas.

"Benefit Factors" are the coefficients that represent the benefit obtained from training a unit in a specific training area. They depend on the scale and type of unit and the category of the training land. We consider all tasks as equally important, although they could be easily differentiated within MSAMT.

MSAMT encourages training as early as possible by using a discount rate. MSAMT's main assumptions are:

- MSAMT only considers units at the battalion level and under, individual training and higher-level training are not considered.
- MSAMT schedules a near-term training period between six and eight weeks as indicated in Field Manual 7-1.
- Each unit performs its required training task iterations successively within the training period.
- For notation purposes, we assume all platoons have an associated company and all companies have an associated battalion. For those platoons under the direct control of battalion or division we create notational companies with no training requirements. Similarly, companies that are under the direct control of division, have a notational battalion, again with no training requirements.
- The units are only scheduled in major training areas. The allocation of the units on the major training areas resides with the person preparing the training scheduling.
- Tasks must be performed in a fixed sequence; the order given in TC 25-1. We assume the tasks are numbered according to this sequence.

- Not all units start at the same level of training proficiency. Different units need to perform different tasks, and they may need to perform the same task a different number of iterations.

B. MODEL FORMULATION

The model in NPS standard form appears below.

1. Sets and Indices

u	unit type	c, cs, css
b	battalion	$b_1, b_2, ...BB$
c	company	$c_1, c_2, ...CC$
p	platoon	$p_1, p_2, ...PP$
t	task	$1, 2, ...T$
a	area	$a_1, a_2, ...AA$
d, d'	available training days	$d_1, d_2, ...DD$

$SetP$ set of allowed platoons

$$\{c.b_1.c_1.p_1, c.b_1.c_1.p_2 .....c.BB.CC.PP \quad etc.\}$$

$SetC$ set of allowed companies

$$\{c.b_1.c_1, c.b_1.c_2 .....c.BB.CC \quad etc.\}$$

$SetB$ set of allowed battalions

$$\{c.b_1, c.b_2 .....c.BB \quad etc.\}$$

2. Parameters

$benp_{ua}$ benefit for training type u platoon in major training area a

$benc_{ua}$ benefit for training type u company in major training area a

$benb_{ua}$ benefit for training type u battalion in major training area a

$disc_d$ discount rate, $disc_d = 0.99^{(d-1)}$

arp_{ubcpt} area required for unit type *u*, battalion *b*, company *c*, platoon *p* to perform task *t* (in accordance with TC 25-1)

arc_{ubct} area required for unit type *u*, battalion *b*, company *c* to perform task *t* (in accordance with TC 25-1)

arb_{ubt} area required for unit type *u*, battalion *b* to perform task *t* (in accordance with TC 25-1)

drp_{ubcpt} days required for unit type *u*, battalion *b*, company *c*, platoon *p* to perform task *t* (in accordance with TC 25-1).

drc_{ubct} days required for unit type *u*, battalion *b*, company *c* to perform task *t* (in accordance with TC 25-1)

drb_{ubt} days required for unit type *u*, battalion *b* to perform task *t* (in accordance with TC 25-1)

$area_a$ size of major training area *a* in km^2

$firstP_{ubcp}$ beginning task number for unit type *u*, battalion *b*, company *c*, platoon *p*

$firstC_{ubc}$ beginning task number for unit type *u*, battalion *b*, company *c*

$firstB_{ub}$ beginning task number for unit type *u*, battalion *b*

3. Decision Variables

$XP_{ubcptad}$ binary variable; "1" if unit type *u*, battalion *b*, company *c*, platoon *p*, starts task *t* in the area *a* on day *d*. "0" otherwise.

XC_{ubctad} binary variable; "1" if unit type *u*, battalion *b*, company *c* starts task *t* in the area a on day *d*. "0" otherwise.

XB_{ubtad} binary variable; "1" if unit type *u*, battalion *b* starts task *t* in the area *a* on day *d*. "0" otherwise.

4. Objective Function and Constraints

Maximize

$$\left\{ \begin{array}{ll} \sum_{(u,b,c,p)\in SetP, t|(t\geq firstP_{ubcp}), a, (d|d\leq DD-drp_{ubcpt}+1)} & disc_d\ benp_{ua}\ XP_{ubcptad} \quad + \\ \sum_{(u,b,c)\in SetC\wedge(drc_{ubct}>0), t|(t\geq firstC_{ubc}), a, (d|d\leq DD-drc_{ubct}+1)} & disc_d\ benc_{ua}\ XC_{ubctad} \quad + \\ \sum_{(u,b)\in SetB\wedge(drb_{ubt}>0), t|(t\geq firstB_{ub}), a, d|(d\leq DD-drb_{ubt}+1)} & disc_d\ benb_{ua}\ XB_{ubtad} \end{array} \right\}$$

Subject to:

$$\left(\begin{array}{l} \sum_{t|(t\geq firstP_{ubcp}), a} \ \sum_{d'=d-drp_{ubcpt}+1}^{\min(d, DD-drp_{ubcpt}+1)} XP_{ubcptad'} \quad + \\ \sum_{(t|(t\geq firstC_{ubc}), a)|drc_{ubct}>0} \ \sum_{d'=d-drc_{ubct}+1}^{\min(d, DD-drc_{ubct}+1)} XC_{ubctad'} \quad + \\ \sum_{(t|(t\geq firstB_{ub}), a)|drb_{ubt}>0} \ \sum_{d'=d-drb_{ubt}+1}^{\min(d, DD-drb_{ubt}+1)} XB_{ubtad'} \end{array} \right) \leq 1 \quad \forall (u,b,c,p)\in SetP, d \qquad (1)$$

$$\sum_{a,d|d\leq DD-drp_{ubcpt}+1} XP_{ubcptad} \leq 1 \qquad \forall (u,b,c,p)\in SetP, t|(t\geq firstP_{ubcp}) \qquad (2)$$

$$\sum_{a,d|d\leq DD-drc_{ubct}+1} XC_{ubctad} \leq 1 \qquad \forall (u,b,c)\in SetC\wedge(drc_{ubct}>0), t|(t\geq firstC_{ubc}) \qquad (3)$$

$$\sum_{a,d|d\leq DD-drb_{ubt}+1} XB_{ubtad} \leq 1 \quad \forall (u,b)\in SetB\wedge(drb_{ubt}>0), t|(t\geq firstB_{ub}) \qquad (4)$$

$$\left(\begin{array}{l} \sum_{(u,b,c,p)\in SetP, t|(t\geq firstP_{ubcp}),a} \sum_{d'=d-drp_{ubcpt}+1}^{\min(d,DD-drp_{ubcpt}+1)} XP_{ubcptad'}\, arp_{ubcpt} + \\ \sum_{(u,b,c)\in SetC\wedge(drc_{ubct}>0),t|(t\geq firstC_{ubc}),a} \sum_{d'=d-drc_{ubct}+1}^{\min(d,DD-drc_{ubct}+1)} XC_{ubctad'}\, arc_{ubct} + \\ \sum_{(u,b)\in SetB\wedge(drb_{ubt}>0),t|(t\geq firstB_{ub}),a} \sum_{d'=d-drb_{ubt}+1}^{\min(d,DD-drb_{ubt}+1)} XB_{ubtad'}\, arb_{ubt} \end{array} \right) \leq area_a \quad \forall a,d \quad (5)$$

$$\sum_{a,d'=1,t=T}^{\min(d,DD-drp_{ubcpt}+1)} XP_{ubcptad'} \geq \sum_{a,d'=1,t=firstC_{ubc}}^{\min(d,DD-drc_{ubc1}+1)} XC_{ubctad'} \quad \forall (u,b,c,p)\in SetP,d \qquad (6)$$

$$\sum_{a,d'=1,t=T}^{\min(d,DD-drc_{ubct}+1)} XC_{ubctad'} \geq \sum_{a,d'=1,t=firstB_{ub})}^{\min(d,DD-drb_{ub1}+1)} XB_{ubtad'} \quad \forall (u,b,c)\in SetC\wedge(drc_{ubct}>0),d \quad (7a)$$

$$\sum_{a,d'=1,t=T}^{\min(d,DD-drp_{ubcpt}+1)} XP_{ubcptad'} \geq \sum_{a,d'=1,t=firstB_{ub})}^{\min(d,DD-drb_{ub1}+1)} XB_{ubtad'} \quad \forall (u,b,c,p)\in SetP\wedge(drc_{ubct}=0),d \quad (7b)$$

$$\sum_{a,d'=1}^{\min(d,DD-drp_{ubcpt}+1)} XP_{ubcptad'} \geq \sum_{a,d'=1}^{\min(d,DD-drp_{ubcpt}+1)} XP_{ubcp(t+1)ad'} \quad \forall (u,b,c,p)\in SetP,t|(t\geq firstP_{ubcp}),d \quad (8)$$

$$\sum_{a,d'=1}^{\min(d,DD-drc_{ubct}+1)} XC_{ubctad'} \geq \sum_{a,d'=1}^{\min(d,DD-drc_{ubct}+1)} XC_{ubc(t+1)ad'} \quad \forall (u,b,c)\in SetC\wedge(drc_{ubct}>0),t|(t\geq firstC_{ubc}),d \quad (9)$$

$$\sum_{a,d'=1}^{\min(d,DD-drb_{ubt}+1)} XB_{ubtad'} \geq \sum_{a,d'=1}^{\min(d,DD-drb_{ubt}+1)} XB_{ub(t+1)ad'} \quad \forall (u,b)\in SetB\wedge(drb_{ubt}>0),t|(t\geq firstB_{ub}),d \quad (10)$$

5. Brief Description of the Objective Function and Constraints

Objective Function: The objective function expresses total benefit from assigned training and consists of three parts; battalion, company and platoon.

Some of the variables at the end of the training cycle are excluded; no task should be scheduled if its completion is not within the specified training cycle.

There is a discount rate for each day in order to give preference to training as early as possible.

The variables with respect to some of the training tasks are excluded from the objective function because not all tasks are to be performed by a unit. Only the variables with respect to the tasks whose number is greater than or equal to associated $firstP_{(u,b,c,p)}$, $firstC_{(u,b,c)}$ or $firstB_{(u,b)}$ are allowed to appear in the objective function.

The variables with respect to notational units are also excluded from the model, because they have no training requirements.

Constraint-1: A platoon, company or battalion can only be given one task at a time, and it cannot be given any other task until the task given is completed, requiring $drp_{(u,b,c,p.)}$, $drc_{(u,b,c)}$ or $drb_{(u,b)}$ respectively.

Finally, a platoon, a company and a battalion cannot be scheduled simultaneously if they are within the same structure. In other words, if a platoon is scheduled, for example, then the company it is subordinate to cannot be scheduled at the same time.

Constraint-2, 3, and 4: A task for a platoon, company or battalion can only be scheduled once. Remember the assumption that the number of iterations occurs consecutively, so scheduling a platoon, company or battalion once for a task means that this scheduling includes all the iterations needed for that specific task.

Constraint-5: On any given day, in any major training area, the total area allocated to every platoon, company and battalion should not exceed the total area of that major training area. When a unit is scheduled, it must be given as much area as required for that particular task in TC 25-1.

Constraint-6, 7a, and 7b: Platoons should be scheduled before their respective companies (constraint-6). However for those platoons directly under battalion control, the scheduling should be before their respective battalions because they have no related companies that need training (constraint-7b). Companies should be scheduled before their respective battalions (constraint 7a). Because tasks are also given priority among themselves, it suffices to compare the day when the last task for a platoon or a company is scheduled and the day when the first task for a company or battalion is scheduled.

Constraint-8, 9 and 10: The training of the tasks should be conducted in a reasonable sequence to be defined by the decision maker. In this respect, task-A for example, should be before task-B for platoon p, company c or battalion b**.** The task order given by TC 25-1 is maintained.

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IV. SAMPLE STUDY

This chapter describes an implementation of MSAMT with a sample data set. The data set is based on Gillman [1993] for units located at Fort Hood, Texas and the major training areas at this base as of 1993.

A. THE SAMPLE DATA SET

1. Benefit Factors

Each level of training uses different benefit factors. Tables 2, 3, and 4 show the benefit factors used in this thesis for platoon, company and battalion level units respectively.

		Area Category		
		Go	Slow Go	No Go
Unit Type	Combat	15	10	0
	Combat S.	10	15	5
	Combat S.S.	10	15	5

Table 2. Benefit Factors for Platoon Level Units

		Area Category		
		Go	Slow Go	No Go
Unit Type	Combat	45	30	0
	Combat S.	30	45	15
	Combat S.S.	30	45	15

Table 3. Benefit Factors for Company Level Units

		Area Category		
		Go	Slow Go	No Go
Unit Type	Combat	135	90	0
	Combat S.	90	135	45
	Combat S.S.	90	135	45

Table 4. Benefit Factors for Battalion Level Units

2. Training Areas

As previously mentioned, the training areas of interest are the major training areas. In our sample study, all available training lands are grouped into major training areas. Table 5 shows the major training areas and their categories in terms of the capability to offer appropriate maneuver conditions for the units to receive training. Gillman[1993] provides a map of these areas.

Major Training Areas	Size (KM^2)	Category
A1	280	GO
A2	84.6	GO
A3	36.6	SLOW-GO
A4	88.5	SLOW-GO
A5	24.7	SLOW-GO
A6	17.7	SLOW-GO
A7	9.89	SLOW-GO

Table 5. Major Training Areas Used in Sample Study

3. Units and Their Respective TC 25-1 Maneuver Training Requirements

The units, their tasks, the number of days and amount of area required for each task appear in the Appendix. There are 261 platoon-level, 67 company-level and 18 battalion-level units in the data set.

4. Creating a Training Subset

The Appendix lists all the units located at the base, but for any real-world implementation only a subset of the units and tasks could be required during any six to eight-week training period. We use a training subset of overall platoon, company and battalion-level units. None of the platoons in our subset are subordinate to any of the companies in the subset, and similarly none of the companies in the subset are subordinate to any of the battalions in the subset. In this study, we implement both a six-week and an eight-week planning period (30 and 40 weekdays respectively). From the data set, almost 65% (63 platoons, 16 companies and 5 battalions) of all the units are first chosen and then 80% (75 platoons, 20 companies and 6 battalions).

5. Defining the Initial Conditions for Units

Having defined the training subsets, it is then necessary to specify the initial training conditions of the units. Since not all the units possess the same level of proficiency, each unit is assigned a number that represents how many tasks they need to perform, as well as a number indicating how many iterations are needed for a specific task. In reality, these requirements are known but here we use a uniform distribution to select both the number of missions required and the number of iterations needed. The assumption is that the number of tasks to be performed is uniformly distributed between one and the number of required tasks specified in TC 25-1 (the total number of tasks that

needs to be performed annually). In this respect MSAMT randomly selects 151 platoon-level, 51 company-level and 11 battalion-level tasks when we have 65% of the units in our training subset. Having 80% of the units in the training set, it selects 187 platoon-level, 62 company level and 11 battalion-level tasks. Similarly, the number of iterations needed for each task is assumed to be uniformly distributed between one and the number of required iterations annually specified in TC 25-1.

B. RESULTS FROM THE SAMPLE STUDY

We use CPLEX 7.5.0 version [ILOG 2002] to solve MSAMT instances and GAMS (The General Algebraic Modeling System) [GAMS 2002] to generate. A typical instance has about 28,000 constraints and 81,500 binary variables when considering 65% of the units for a 6-week time period. After 24 hours, CPLEX only had a solution guaranteed to be within 20% of optimal. An optimization based heuristic technique solves the problem rather quickly.

Because there are many similar variables, we partition the units into 10 subsets. MSAMT solves for just one of these small subsets, fixes the solution found and then solves for a new subset. This is repeated until all the subsets appear in a solution. For all instances considered, this heuristic technique requires less than an hour to find a solution within 10% of optimal.

1. A Maneuver Training Schedule

Using 65% of all units and six weeks, Table 6 shows a sample MSAMT schedule.

						DAYS																							
Type	BN	CO	Platoon	Task	Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
COMBAT	1st Mech. Inf. BN	Mech Inf. CO-1	**Plt.-1**	t4	Area-2								X																
				t5	Area-2																X								
			Plt.-2	t2	Area-2	X																							
				t3	Area-3					X																			
				t4	Area-4									X															
				t5	Area-1															X									
			Plt.-3	t3	Area-1		X																						
				t4	Area-2								X																
				t5	Area-2																					X			
		Mech Inf. C0-2	**Plt.-1**	t2	Area-2	X																							
				t3	Area-2						X																		
				t4	Area-1								X																
				t5	Area-1													X											
			Plt.-2	t4	Area-1		X																						
				t5	Area-1													X											
			Plt.-3	t4	Area-2	X																							
				t5	Area-1													X											

Table 6. A Sample Training Schedule Obtained for 65% Unit Level and 6-Week Time Period.
Cross marks indicate the start day for each task.

Figure 1 shows the fractional area usage for each day. Areas 6 and 7 are only used at the beginning of the training period. Their small size is too restrictive, even for most of the platoons training. The usage of the other areas is very high, but some slots still exist.

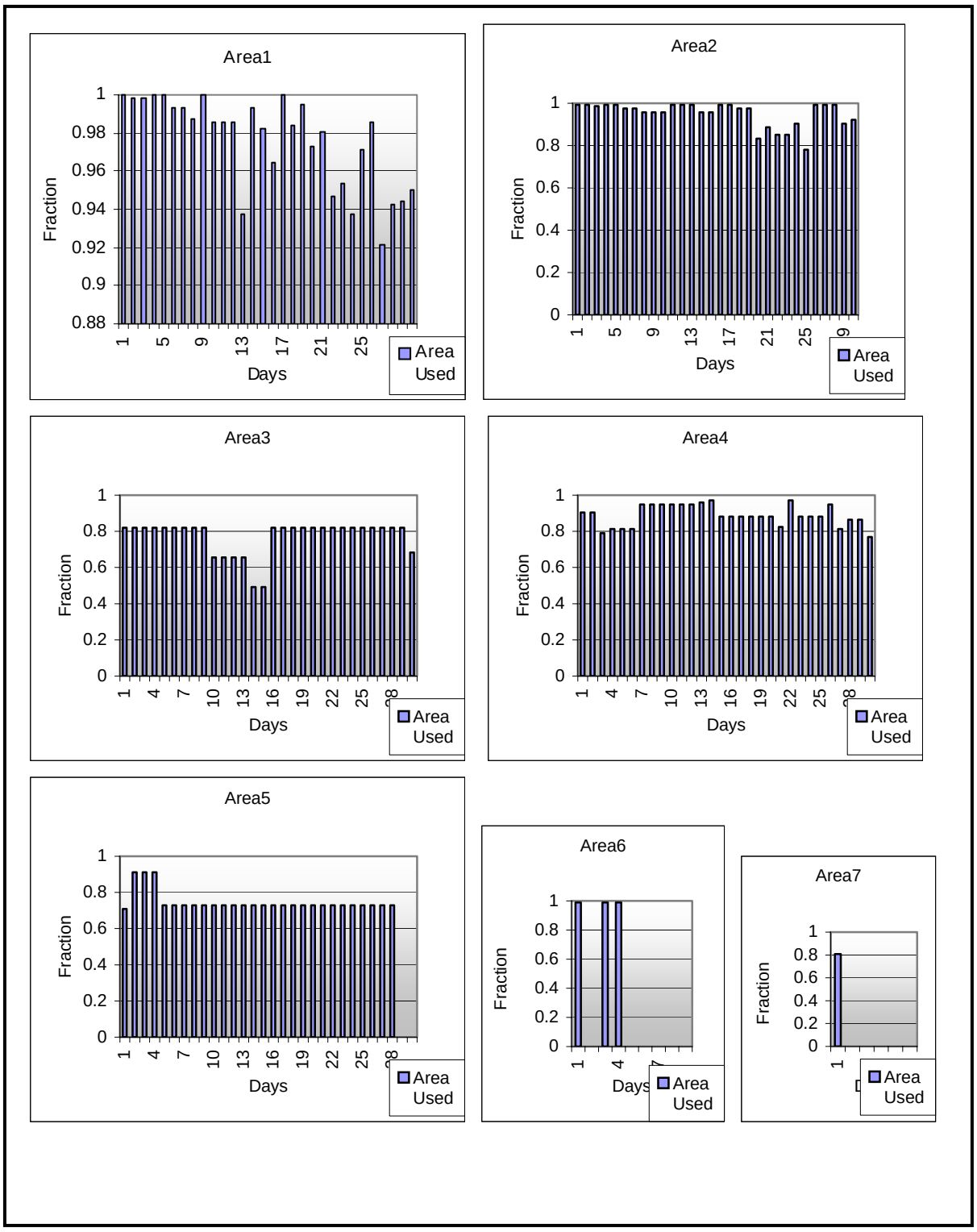

Figure 1. Fractional Area Usage Each Day for 65% Unit Level and 6-Week Time Period.

Areas 6 and 7 have very limited usage due to their small size. The usage for the other areas seems to be very high.

Figure 2 shows the overall area usage during the 6-week training period with 65% of the units participating in the training set.

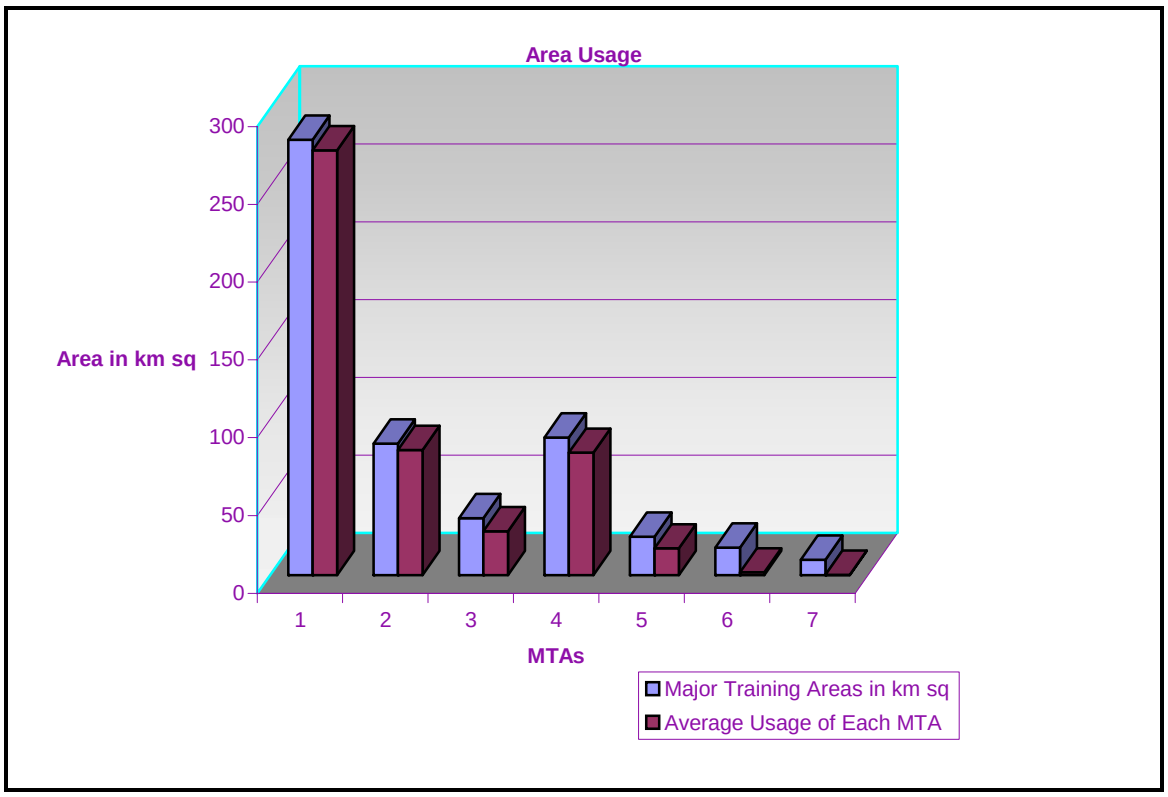

Figure 2. Average Area Usage for 65% Unit Level and 6-Week Time Period Usage of Areas 6 and 7 is very low; other areas are used at a higher percentage.

Table 7 shows training values achieved for each unit level. All the companies and battalions in the training set find the opportunity to complete all their respective training tasks, whereas only 75% of the platoons can do so. Of all the training tasks required by platoons, 82% are completed.

UNIT LEVEL : PLATOON	
Total number of platoons in the training set :	63
Total number of platoons in the training set that completed all the training tasks given :	47
Percent of total number of platoons in the training set that completed all the training tasks given **(P1)** :	74.6%
Percent of total number of tasks achieved by the platoons in the training set **(P2)** :	81.8%
UNIT LEVEL : COMPANY	
Total number of companies in the training set :	16
Total number of companies in the training set that completed all the training tasks given :	16
Percent of total number of companies in the training set that completed all the training tasks given **(C1)** :	100%
Percent of total number of tasks achieved by the companies in the training set **(C2)** :	100%
UNIT LEVEL : BATTALION	
Total number of battalions in the training set :	5
Total number of battalions in the training set that completed all the training tasks given :	5
Percent of total number of battalions in the training set that completed all the training tasks given **(B1)** :	100%
Percent of total number of tasks achieved by the battalions in the training set **(B2)** :	100%

Table 7. Training Values Achieved for Each Level of Units for 65% Unit Level and 6-Week Time Period

Some of the platoons are not able to find the opportunity to train, but all companies and battalions are able to achieve their given tasks.

Table 7 demonstrates that some of the platoons are not able to find an opportunity to train all their given tasks. Table 8 shows these platoons.

Unit Type : Combat							
		PLT1	**PLT2**	**PLT3**	**PLT4**	**PLT5**	**PLT6**
1st Mech Inf Bn	Company-1	100.00%	100.00%	100.00%			
	Company-2	100.00%	100.00%	100.00%			
	Company-3	100.00%	100.00%	100.00%			
	Company-4	100.00%	100.00%	100.00%			
	Company-5	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2nd Mech Inf Bn	Company-1	100.00%	100.00%	100.00%			
	Company-2	100.00%	100.00%	100.00%			
	Company-3	100.00%	100.00%	75.00%			
	Company-4	***60.00%***	100.00%	100.00%			
	Company-5	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
3rd Mech Inf Bn	Company-1	100.00%	100.00%	75.00%			
	Company-2	100.00%	***50.00%***	***100.00%***			
	Company-3	***50.00%***	***0.00%***	***0.00%***			
	Company-4	***50.00%***	***25.00%***	***100.00%***			
	Company-5	100.00%	100.00%	0.00%	100.00%	100.00%	100.00%
Unit Type : Combat Support							
		PLT8	**PLT9**				
1st Mech Inf Bn	Company-5	100.00%	***0.00%***				
2nd Mech Inf Bn	Company-5	100.00%	***66.70%***				
3rd Mech Inf Bn	Company-5	100.00%	***0.00%***				

Table 8. Percentage of Task Achievement by Each Platoon for 65% Unit Level and 6-Week Time Period

Highlighted values show the platoons observed did not complete all their given tasks.

2. Base Ability Assessment

A weighted sum of the percentage training values given in the previous section is used to find a military value for the installation to support maneuver training requirements. We call this a base ability value. The values chosen from Table 7 are the total task achievement **P2, C2, and B2**.

$$base\,ability\,value = \frac{w_p * P2 + w_c * C2 + w_b * B2}{w_p + w_c + w_b}$$

The weights w_p, w_c, and w_b represent the number of platoons. Thus, w_p is the number of platoons in the platoon-level training set, w_c is the number of platoons in the company-level training set, and w_b is the number of platoons in the battalion-level training set. Roughly speaking, there are 3 platoons in a company and 12 platoons in a battalion. Thus, in this case, this value for the base results in

((63)*81.8) + (3*16)*100 +(12*5)*100)/(63+3*16+12*5) = 93.29.

We use this value as an indicator of how well maneuver requirements are satisfied.

3. What If Analysis

MSAMT can easily perform "what if?" analyses. Three cases are described below.

a. What if the Number of Units is Increased?

What if the number of units is increased from 65% to 80%? Table 9 shows the values obtained for an 80% training set. Figure 3 shows the impact of this change. The base ability value drops from 93% to 85%.

UNIT LEVEL : PLATOON	
Total number of platoons in the training set :	75
Total number of platoons in the training set that completed all the training tasks given :	56
Percent of total number of platoons in the training set that completed all the training tasks given **(P1)** :	74.7%
Percent of total number of tasks achieved by the platoons in the training set **(P2)** :	78.8%
UNIT LEVEL : COMPANY	
Total number of companies in the training set :	20
Total number of companies in the training set that completed all the training tasks given :	17
Percent of total number of companies in the training set that completed all the training tasks given **(C1)** :	85%
Percent of total number of tasks achieved by the companies in the training set **(C2)** :	94.2%
UNIT LEVEL : BATTALION	
Total number of battalions in the training set :	6
Total number of battalions in the training set that completed all the training tasks given :	5
Percent of total number of battalions in the training set that completed all the training tasks given **(B1)** :	83.3%
Percent of total number of tasks achieved by the battalions in the training set **(B2)** :	83.3%

Table 9. Training Values Achieved for Each Level of Units for 80% Unit Level and 6-Week Time Period

With 80% of the units in the training set, the level of achieved tasks decreases. See also Figure 3.

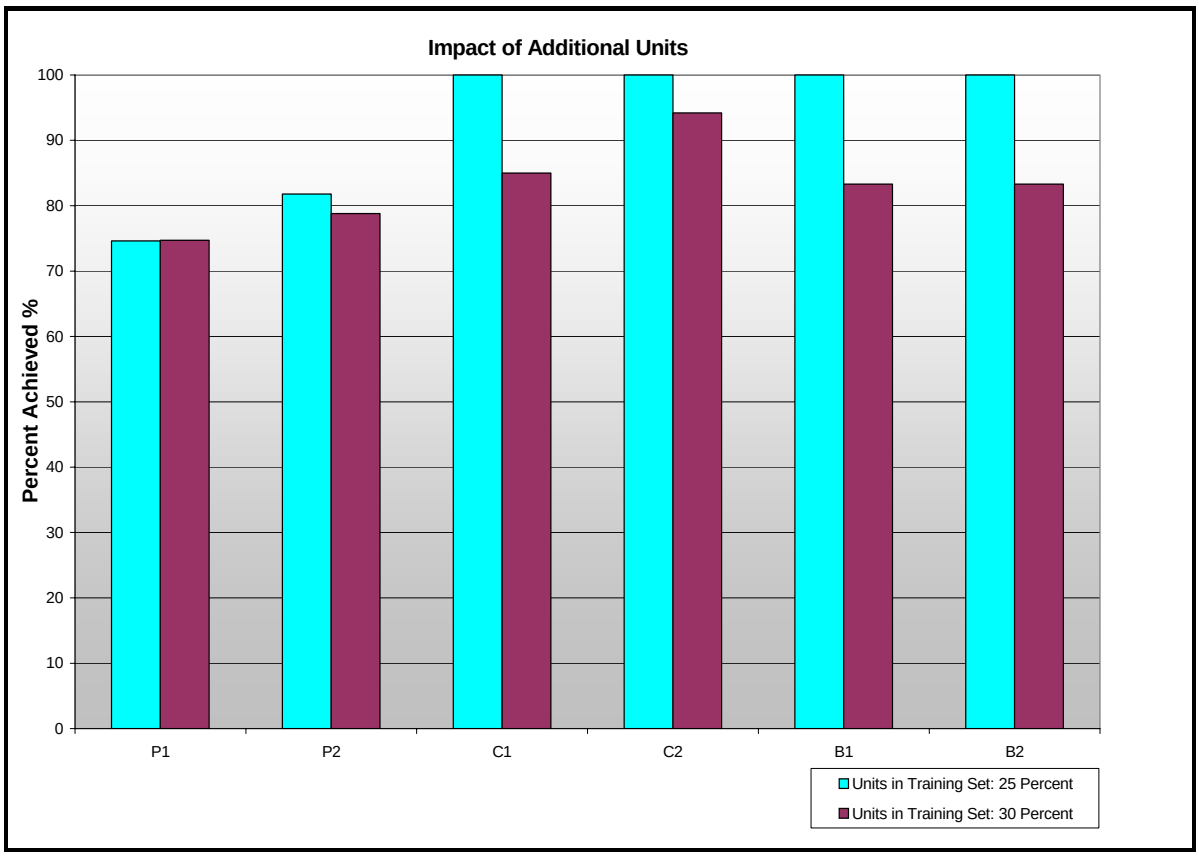

Figure 3. Impact of Additional Units

Having 15% more additional units substantially decreases the task achievement values. See Tables 7 and 9 for the definitions and exact values of P1, P2, C1, C2, B1 and B2.

b. What if the Available Training Time is Increased?

Table 10 shows the values found by extending the time length from 6 weeks to 8 weeks and Figure 4 shows the impact. The base ability value increases from 85% to 94%.

UNIT LEVEL : PLATOON	
Total number of platoons in the training set :	75
Total number of platoons in the training set that completed all the training tasks given :	70
Percent of total number of platoons in the training set that completed all the training tasks given **(P1)** :	93.3%
Percent of total number of tasks achieved by the platoons in the training set **(P2)** :	98.4%
UNIT LEVEL : COMPANY	
Total number of companies in the training set :	20
Total number of companies in the training set that completed all the training tasks given :	20
Percent of total number of companies in the training set that completed all the training tasks given **(C1)** :	100%
Percent of total number of tasks achieved by the companies in the training set **(C2)** :	100%
UNIT LEVEL : BATTALION	
Total number of battalions in the training set :	6
Total number of battalions in the training set that completed all the training tasks given :	5
Percent of total number of battalions in the training set that completed all the training tasks given **(B1)** :	83.3%
Percent of total number of tasks achieved by the battalions in the training set **(B2)** :	83.3%

Table 10. Training Values Achieved for 80% Unit Level and 8-Week Time Period Extending the time length to 8 weeks increases the task achievement values. See also Figure 4.

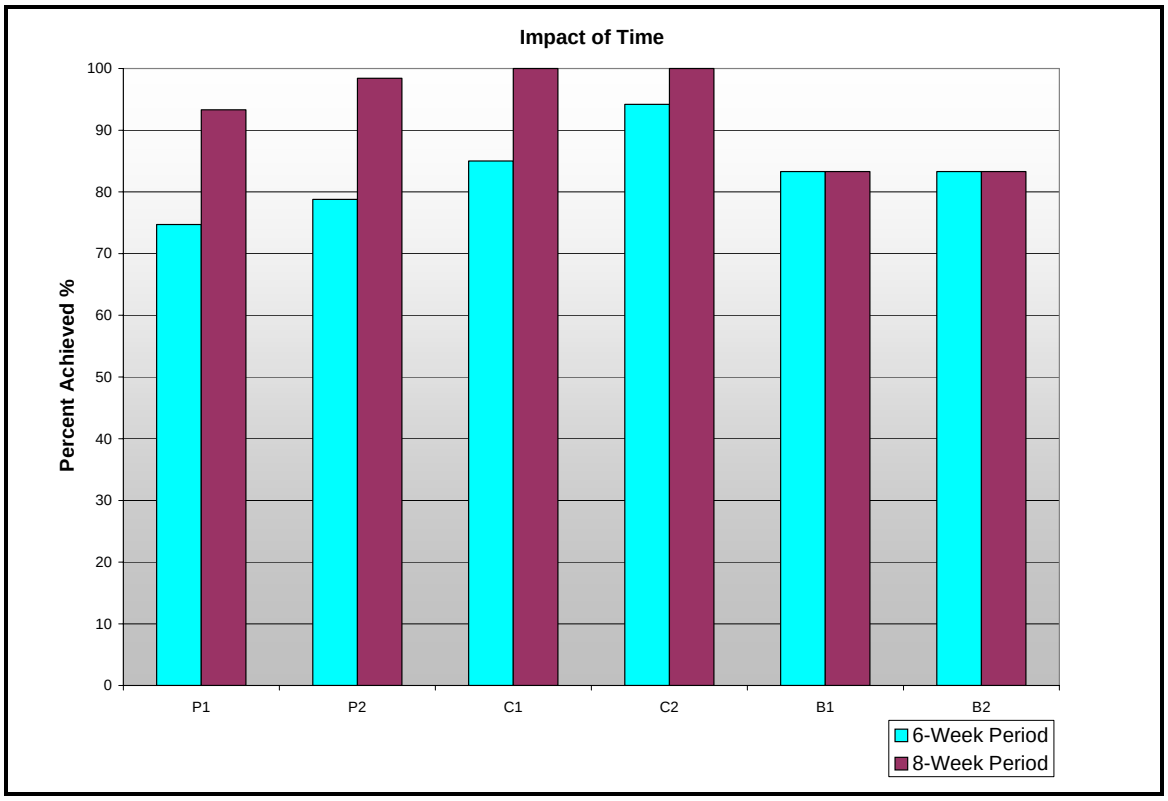

Figure 4. Impact of Additional Time Length

Extending the available time length two more weeks substantially increases the achieved training values. See Tables 9 and 10 for the definitions and exact values of P1, P2, C1, C2, B1 and B2.

c. What if More Land Is Acquired?

Here the area available is increased. The training set is again 80% of the units located at the base and the time length is six weeks. But we assume that an additional 50- km^2 area of "go" land is available. Table 11 shows the values found, and Figure 5 shows the impact. The base ability value increases from 85% to 90%.

UNIT LEVEL : PLATOON	
Total number of platoons in the training set :	75
Total number of platoons in the training set that completed all the training tasks given :	59
Percent of total number of platoons in the training set that completed all the training tasks given **(P1)** :	78.7%
Percent of total number of tasks achieved by the platoons in the training set **(P2)** :	87.2%
UNIT LEVEL : COMPANY	
Total number of companies in the training set :	20
Total number of companies in the training set that completed all the training tasks given :	20
Percent of total number of companies in the training set that completed all the training tasks given **(C1)** :	100%
Percent of total number of tasks achieved by the companies in the training set **(C2)** :	100%
UNIT LEVEL : BATTALION	
Total number of battalions in the training set :	6
Total number of battalions in the training set that completed all the training tasks given :	5
Percent of total number of battalions in the training set that completed all the training tasks given **(B1)** :	83.3%
Percent of total number of tasks achieved by the battalions in the training set **(B2)** :	83.3%

Table 11. Training Values Achieved for 80% Unit Level and 6-Week Time Period with Additional Area.

Having additional area increases the training values achieved. See also Figure 5.

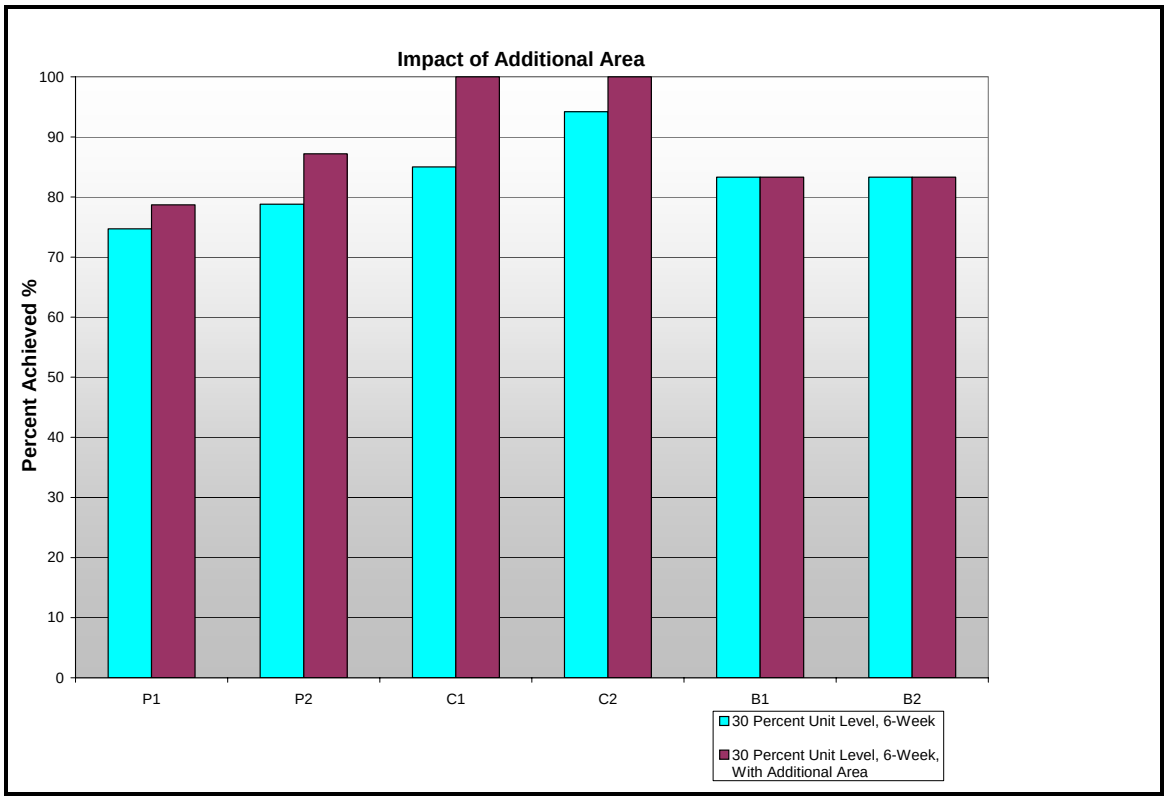

Figure 5. Impact of Additional Area

Adding 50 km^2 more available training land considerably increases the training values achieved. See Tables 9 and 11 for the definitions and exact values of P1, P2, C1, C2, B1 and B2.

V. CONCLUSION

MSAMT is an integer linear program to schedule Army maneuver training. The main input for MSAMT is the maneuver training requirements specified in TC 25-1. The units and the training areas of Fort Hood, Texas are used as a sample data set. The time period covered is 6 to 8 weeks, a near-term Army training plan as specified in Field Manual 7-1.

In our sample implementation for a 6-week training period, 63 platoons, 16 companies and 5 battalions (65% of the units) are randomly chosen for the training set. MSAMT assigns a random initial training level of the units resulting in 151 platoon-level, 51 company-level and 11 battalion-level tasks. MSAMT schedules all required battalion and company tasks but is only able to schedule 75% of the platoon tasks. Using a weighted sum of these platoon, company and battalion percents we aggregate these into a single base ability value of 93%. All training areas are extensively used.

We observe the impact of additional time, area and units. The aforementioned value for Fort Hood, Texas decreases to 85% when 75 platoons, 20 companies, 6 battalions (80% of the units) participate in training and only have 6 weeks. Maintaining the 80% unit level but using an 8-week period, results in 94%, and an 80% unit level for a 6-week time period and adding 50 km^2 more land produces a value of 90%.

In summary, the developed model in this thesis, MSAMT, is capable of answering the following questions: *"How should the maneuver training of the units at a base be scheduled with respect to the time, unit and area available?", "Is the base capable of meeting the maneuver training requirements of its units as specified in TC 25-1?", "Is more land needed for training or is there an excess of training land?", "How much time is needed for a specific training set to complete all its maneuver training?", "What is a reasonable number of units that can complete their maneuver training at an installation?"*

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APPENDIX. UNITS AND TC 25-1 MANEUVER TRAINING REQUIREMENTS

This appendix contains the units located at Fort Hood, Texas as of 1993, their respective ARTEP (Army Training and Evaluation Program) missions and the amount of land as well as the number of days and iterations required for those units to perform each of these tasks.

SAMPLE CASE- UNITS AND TC 25-1 REQUIREMENTS

		MECHANIZED BATTALION UNITS				Annual	
Unit Type	Unit	Quantity	Mission Name	Land Required	Iteration Required	Day Required Per Iteration	Total Day Required Per Mission
Combat	MECH IN BN.	5					
			Movement to Contact	248	4	1	4
			Offense	68	4	1	4
			Defense	138	4	1	4
			Retrogade	138	4	1	4
Combat	MECH IN CO.	20					
			Movement to Contact	84	3	1	3
			Attack	50	3	1	3
			Defend	24	3	2	6
			Retrogade	102	3	2	6
			Raid	24	3	1	3
			Ambush	50	3	1	3
Combat	MECH IN RIFLE PLT.	60					
			Offense	24	4	2	8
			Defense	18	4	2	8
			Retrogade	30	4	2	8
			Stability	18	4	2	8
			Support	18	4	2	8
PLATOONS UNDER BATTALION CONTROL							
Combat	ANTI-TANK PLT.	4					
			Offense	60	3	1	3
			Defense	28	3	1	3
			Retrogade	30	3	1	3
			Stability	30	3	1	3
			Support	30	3	1	3

Combat	MORTAR PLT.	5					
			Offense	60	2	1	2
			Defense	28	2	1	2
			Retrogade	30	2	1	2
			Stability	18	2	1	2
			Support	18	2	1	2
Combat	SCOUT PLT.	5					
			Security Operations	120	4	1	4
			Recon Operations	120	4	1	4
Combat	SUPPORT PLT.	5					
			Provide Logistical Support	20	3	1	3
Combat	MEDICAL PLT.	5					
			Provide Health Services	8	3	1	3
Combat	MAINTENANCE PLT.	5					
			Provide Maintenance Service	4.5	3	1	3
			Conduct Recovery Operations	4.5	3	1	3
Combat	SENSOR PLT.	5					
			EW in Offense	50	4	1	4
			EW in Defense	25	4	1	4
			EW in Movement	24	4	1	4
Combat S.	VULCAN PLT.	10					
			ADA: Static vs Low -Altitiude Hostile Target	25	2	1	2
			ADA: Static vs Low -Altitiude Mobile Target	8	2	1	2
			ADA: Mobile vs Low -Altitiude Hostile Target	25	2	1	2

			ARMOR BATTALION UNITS			Annual	
Unit Type	Unit	Quantity	Mission Name	Land Required	Iteration Required	Day Required Per Iteration	Total Day Required Per Mission
Combat	ARMOR BN.	8					
			Movement to Contact	248	4	1	4
			Offense	68	4	1	4
			Defense	138	4	1	4
			Retrogade	138	4	1	4
Combat	TANK CO.	32					
			Movement to Contact	30	3	1	3
			Attack	17.5	3	1	3
			Defend	3	3	1	3
			Retrogade	22.5	3	1	3
			Security	24	3	1	3
Combat	TANK PLT.	96					
			Move	20	3	1	3
			Attack	3	3	1	3
			Defend	0.5	3	1	3
PLATOONS UNDER BATTALION CONTROL							
Combat S.	STINGER PLT.	8					
			AD for static asset	25	4	2	8
			AD for mobile asset	25	4	2	8
			AD for movement to contact	25	4	2	8
			AD for breaching operations	25	4	2	8
Combat S.	VULCAN PLT.	8					
			ADA: Static vs Low -Altitiude Hostile Target	25	2	1	2
			ADA: Static vs Low -Altitiude Mobile Target	8	2	1	2
			ADA: Mobile vs Low -Altitiude Hostile Target	25	2	1	2

			FIELD ARTILLERY BATTALION UNITS			Annual	
Unit Type	Unit	Quantity	Mission Name	Land Required	Iteration Required	Day Required Per Iteration	Total Day Required Per Mission
Combat	FIELD ARTILLERY (FA) BN.	3					
			Deliver Fires	465	4	3	12
			Move	45	12	1	12
Combat	FA HEADQUAR-TERS AND HEADQUAR-TER'S BATTERY 155 mm SP	3					
			Move	15	12	1	12
Combat	SERVICE BATTERY 155 mm SP	3					
			Move	15	12	1	12
Combat	FA PLATOON 155 mm SP	9					
			Deliver Fires	93	2	2	4
			Move	4	12	1	12
PLATOONS UNDER BATTALION CONTROL							
Combat	FA PLATOON MLRS	3					
			Deliver Fires	72	2	1	2
			Move	9	12	1	12

			ENGINEER BATTALION UNITS			Annual	
Unit Type	Unit	Quantity	Mission Name	Land Required	Iteration Required	Day Required Per Iteration	Total Day Required Per Mission
Combat S.	ENGINNER BATTALION	2					
			Mobility Operations	192	2	1	2
			Countermobility Operations	192	2	1	2
			Survivability Operations	192	2	1	2
			General Engineering	192	2	1	2
			Fight As Engineers	102	2	1	2
Combat S.	ENGINNER COMPANY	8					
			Mobility Operations	96	2	1	2
			Countermobility Operations	96	2	1	2
			Survivability Operations	96	2	1	2
			General Engineering	96	2	1	2
			Fight As Engineers	84	2	1	2
Combat S.	ENGINNER PLT.	24					
			Mobility Operations	48	2	1	2
			Countermobility Operations	48	2	1	2
			Survivability Operations	48	2	1	2
			Sustainment Engineering	48	2	1	2

			UNITS UNDER DIVISION CONTROL			Annual	
Unit Type	Unit	Quantity	Mission Name	Land Required	Iteration Required	Day Required Per Iteration	Total Day Required Per Mission
Combat S.	BRIDGE CO	1					
			Fixed Bridge Operations	96	2	1	2
			Float Bridge Operations	96	2	1	2
Combat S.	BRIDGE PLT.	3					
			Fixed Bridge Operations	96	2	1	2
			Float Bridge Operations	96	2	1	2
Combat S.S	NBC RECONAISS-ANCE PLT.	1					
			NBC Recon (Route)	10	4	1	4
			NBC Recon (Zone)	50	4	1	4
			NBC Recon (Area)	9	4	1	4
			NBC Survey	20	4	1	4
			Conventional Recon	25	4	1	4
Combat S.S	DECONTAMI-NATION PLT.	4					
			Operate Personnel Decon	3	4	1	4
			Operate Hasty Decon (12 Hour)	9	4	1	4
			Operate Hasty Decon (24 Hour)	3	4	1	4
Combat S.S	SMOKE GENERA-TING PLT.	1					
			Smoke Operations	100	6	1	6
			Conceal River Crossing	25	6	1	6
			Decontamination Operations	9	6	1	6
			Conceal a Breach Operation	25	6	1	6

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